

THE EFFECT OF UNUSUAL STIMULATION ON
MOTOR COORDINATION IN CHILDREN

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THE ability of children to coördinate their reactions in response to a stimulus pattern that involves one or more unusual stimuli is a problem of learning. A study of the progress in coördination of the movements of the hand which the child can make with visual and electro-tactual stimuli recurring at regular intervals appeared to be of value in finding not only whether the child is or is not able to make the correct responses, but also in giving an analysis of the types of responses made in the attempts to learn such a problem.

In this problem are involved some factors which have been previously investigated in connection with studies on the complication experiment, simple reaction time experiment, synchronic reaction experiment, and problems involving hand-eye coördination. Because of these implications a brief historical survey will be given of this work.

In the latter part of the eighteenth century astronomers were interested in the errors of estimation made by observers. It was found that in the "eye and ear" method of fixing the instant when the star in its transit crossed the reticle of the telescope, individuals varied in their attempts to synchronize the time of the passing of the star with the beat of the clock.

The differences in errors of estimation were dependent upon a factor which was termed the "personal equation." Principally from the works of Bessel, Struve, Argelander, Gill, Wolf, and Rogers (30) it was found that the nature of the object observed, its magnitude, its direction and rate of movement, and the illumination of the field were influential upon the estimates; likewise that the position of the observer, his physical condition, the habits set up by the rhythmic recurrence of the stimuli, the knowledge of the amount and direction of the errors, and the direction of attention were all factors that influenced the amount and direction of the error of estimation.

From these investigations on the personal equation there developed a type of experiment dealing with an analogous problem and termed the "complication experiment." The term was devised by Wundt to apply to the study of the temporal relation of a single impression introduced suddenly into a continuous series of impressions. The first experiment made by Wundt was one in which the reactor watched an index-hand traverse a graduated circular dial, while listening to a series of sounds which had the same rhythmic period as the revolutions of the index-hand. The subjects then attempted to judge the position

of the hand coincident with the sound. The purposes of the two types of experiments, the personal equation and the complication reaction, were analogous in that there was to be found the coincidence of the star and the meridian on the one hand, and the synchronization of the index-hand with the sound on the other. In both experiments two types of errors were made: (1) the assumed coincidence which was made prior to the actual coincidence, termed a negative error, and (2) the assumed coincidence was made later than the actual coincidence and called the positive error.

From the early studies which have been reviewed by Burrow (8) and from later studies by Dunlap (9) and Yoa-kum (39) the following facts were found: (1) Both rate and practice influence the amount and direction of the error; (2) The eye movements occurring with the upward and downward movement of the index-hand had a decided influence on the direction of the error; (3) The type of error made was influenced by the direction of the attention. If the visual stimulus were attended to, there occurred a preponderance of positive errors, while more negative errors occurred when attention was centered on the auditory stimulus; (4) The differences in results when the impressions were presented to one sense or to two senses were practically negligible relative to the type and number of errors; (5) Two general types of judgments were made—"spatial" and "temporal." The "spatial" judgment was that which was made when the subject perceived the spatial position of the discrete stimulus in relation to the align-

ment; the "temporal" was that which was made when the subject perceived the temporal relation between the two stimuli. This analysis aided in determining the type of errors made under certain conditions; (6) Types of fixation (natural, exact, pointer-pursuit) have been studied and show a direct relation to the amount and direction of the error.

The next phase of the complication problem which was studied was that of rhythmic reactions. In these experiments the subject was required to synchronize a reaction (tapping a key) to a sound or flash which was repeated regularly at several different rates. From the studies of Scripture (31, 32), Johnson (19), Mijake (22), and Dunlap (10), the results were found to be similar to those in the complication experiment. Anticipated and lagged reactions were made to both modes of stimuli. The amount and direction of the error were influenced by the rate of the stimulus and by practice. The direction of attention either to the stimulus or to the reaction had a varying influence on the type of reaction made by different individuals. The reaction to the auditory stimulus was slightly earlier than that made to the visual stimulus. Because of the brief duration of the stimuli accurate synchronization rarely occurred.

The simple reaction time experiment arose in connection with these two problems. A current definition of reaction time is "the period elapsing between the application of a 'stimulus' and the beginning of the 'action' which the stimulus initiates." The work of Cattell (12) and his co-workers and students has shown that

some of the factors and conditions which influence the reaction time are: the sense organ stimulated; the intensity, size, and duration of the stimulus; the length of the fore-period; the type of the reacting movement; practice, attention, distraction, and fatigue; incentives, punishment, drugs, and age; and individual differences themselves. The simple reaction differs essentially from the complication and synchronic reactions in that in the latter two the stimuli are recurring rhythmically and several stimulations are to be reacted to. In the simple reaction experiment only "one" reaction is made to "one" stimulus.

The complication and synchronic experiments have been made only with adults as subjects. It was one purpose of the present experiment to see what children of young ages would do in similar situations.

Ability of pre-school children in eye-hand coordinations was studied by Johnson (18), Baldwin and Stecher (3), Wellman (35), and Gesell (13). These investigators used the beat of a metronome as a recurring stimulus. Their results showed age differences. Some found sex differences aside from definite and wide individual variations. Studies of children over six years of age are those of Bryan (6), Whipple (37), Heinlein (15), Bolton (5), Bagley (2), Glenn (14), Wilson (36), and Jones (20). Again, some form of hand movement was to be made in coincidence with a recurring sound. The results for the total accuracy as well as accuracy for each stroke, although not of synchronization, showed age differentiation. Bolton and Bagley found sex differences, and Wilson and Jones

found a positive relation between intelligence and the score.

For the studies on adults, aside from those previously discussed, in which synchronization was a factor, those of Bogardus (4) and Perrin (26) are notable. Both used experimental situations in which the subject was required to place a one inch cube on a designated one inch square. A block was picked up from a box with the right hand and placed on the square. It was to be removed with the left hand and placed in a funnel by which it was returned to the starting box. The blocks were to be placed at the rate of one a second. A revolving arm (one revolution a second) was so connected that its path lay over the square. If the block were not removed, the revolving arm would hit it. The square was connected electrically so that a record could be made of any displacement of the block (accuracy score). A record of the revolving arm showed the accuracy of synchronization of each placement. Both investigators found wide individual variation and a tendency toward greater inaccuracy with the use of faster rates and longer work periods.

Still another important factor which is involved in the present study is that termed "motivation" and its effect upon "learning." The problem of motivation has been of interest to experimental psychology from a fairly early stage in the development of that science to the present day. From the beginning of interest in this problem, punishment or pain has been one of the favorite modes of studying motivation. Among the forms of punishment adopted, the electric shock has prob-

ably been used more extensively than any other. The electric shock as a motivating factor in any kind of learning or behavior experiment belongs to that type of incentive to which the animal or individual reacts negatively. It has been referred to rather loosely as a "negative motivation."

The study of motivation on humans developed from investigations of animal motivation. For the most part similar problems with similar methods were studied. Electrical stimulation as a motivating factor has been used on humans in studying muscular contractions, reaction time, accuracy of movement, rate of movement, discrimination, and inhibition of response. Miller (21) studied the effect of muscular contraction and relaxation on the non-voluntary response to an electric shock. It was found that during the relaxed condition the extent of the arm movement was decreased; the reaction time of the movement was increased; and the apparent intensity or unpleasantness of the shock was diminished. Johanson (16) studied the influence of an electric shock as punishment upon reaction time. He found that the actual percentage saved in the punishment series as compared with the normal series was 14.8 per cent or 20 sigma. Rexroad (28) investigated the effect of the electric shock on accuracy of reaction to a continuous multiple choice problem. He concluded that the punishment had three effects—disruptive, incentive, and instructive. However, the resultant of the three effects in no case offset the effects from individual differences and daily fluctuations. Bunch (7) investigated the effect of a definite intensity of electric shock on

adult human maze learning. She found that there was a 50 per cent reduction in the number of trials; decrease in the number of errors; and 34 per cent decrease in time per trial as a result of the intensity of shock used. Vaughn and Diserens (34) studied the comparative effects of three intensities of electrical punishment on Learning a maze. The experiment showed that light and medium intensities were most efficacious for learning as measured by errors and time. Vaughn's study (33) of the effects of positive and negative instructions in producing inhibitory behavior showed the superiority of the actual punishment (electric shock) over other motives. There were found to be large individual differences, and the children were less influenced than adults. For all the subjects the effects of negative instruction not accompanied by shock wore off rapidly. McTeer (25) investigated the effect of an electric shock as punishment in a ten-unit finger-response multiple-choice serial-order learning problem, and the effect of the shock when applied to the ankle as compared to the effect when applied to the reacting finger. The experiment showed that the punished group learned the problem with fewer trials and fewer errors than the non-punished group. Also, when the intensity was kept constant, the differences in results from differences in application were negligible. McTeer reports two unpublished studies carried out at the University of Wisconsin which investigated the effect of punishment applied to the reacting hand in maze learning as compared to the effect when punishment was applied to the non-reacting hand. One experimenter

found that punishment applied to the reacting hand was more efficacious in the learning problems. The other found practically no significant differences in the results of two groups, one with and one without shock.

PROBLEM AND APPARATUS

The specific problem of the present investigation was to study the ability to learn to synchronize a finger reaction with a recurring flash of light, and to analyze the development of this synchronization.

For this experiment an apparatus was devised so that a study could be made of the way in which reactions were modified in development of co-ordination, and the effect of unusual stimuli upon this coördination.

The experiment consisted chiefly of a stimulus (a red light) flashing intermittently at a rate of once every two seconds. The duration of the flash was two-thirds of a second, and the interval between flashes was one and one-third seconds. The response to the stimulus was the depression of a reaction key. If the key were pressed when the light was on, a bell would ring; while, if the key were pressed when the light was off, the bell would not ring. An electric shock circuit was connected so that in parts of the experiment, whenever the key was pressed when the light was not on, a slight shock (.2 milliampere) would be received by the subject. This electro-tactual stimulation caused a slight pricking or tickle effect. A kymographic record was made of both the stimuli and the reactions.

This experiment was somewhat sim-

ilar to other studies in which rhythmic stimuli were used in that the stimulus was responded to by the depression of a key. However, it differs in that the stimulus was not instantaneous but had a duration. This made it possible for many correct synchronic reactions to be made; whereas in reactions to stimuli of very brief duration, the exact synchronization rarely, if ever, occurs. Also, in previous synchronic experiments, work was done both with and without knowledge of the results, the knowledge being obtained from the scores or from the record after the test trial. In this experiment the ringing of the bell indicated the correctness of the response; the electric shock was also a check on the correctness of the response. Thus for each reaction, the subject knew whether or not the response was accurate.

It was found that the children liked the bell and worked to make it ring. In this way the bell acted as a positive motivation. The shock was disliked and effort was made to react so as to avoid it. In this way the shock served as a negative motivation. The experiments in which the electric shock has been used as a punishment have been those in learning and in reaction times, but the shock has never, to the author's knowledge, been used in experiments with the rhythmic stimulation. It has not been used on such young ages, although the threat of a shock has been used to inhibit movement—Vaughn (62).

The apparatus itself consisted essentially of four main units—the stimulus unit, the reaction unit, the shock unit, and the recording unit. The four units were coördinated, but for explan-

atory purposes they will be taken up separately.

The stimulus unit consisted of a synchronous motor (Dunlap model) which was used to drive four commutators arranged in pairs. The separate commutators for each pair were so constructed that either could be adjusted with respect to the other in order that the relative period during which the commutator brushes were in contact with both members of the pair of commutators could be varied over a relatively wide range. This permitted a variation in the relative amount of time the commutators were closed to the amount of time they were open for any given rate of speed. The absolute rate of the rhythmic stimulation was controlled as follows. On the shaft which carried the bank of commutators were several drive wheels of varying circumferences. The drive belt from the synchronous motor could be looped over any one of these and the speed with which the commutators revolved depended upon the size of the drive wheel used, since the speed of the synchronous motor was constant. One pair of commutators was set so that a circuit was opened and closed causing the light to flash intermittently at the rate and with the duration desired.

The reaction unit consisted of a reaction key, the button of which was insulated by a sheet of bakelite from the remainder of the key. The circuit through one recording pen remained closed, when the key was untouched, and was broken when the key was depressed; this circuit could be made and broken independent of the commutators of the control mechanism. In a second circuit, the stimulus light was

connected in a series with one set of commutators. Whenever these commutators were in a position to close this circuit the light would flash. In addition to this a small electric bell was connected in series with the same set of commutators in such a way that the closing of the circuit through the reaction key would cause it to ring. Another factor in the reaction was the possibility of an electric shock. This will be explained in the following section.

Reference may be made for the construction of the electrical unit to Dunlap (21). This consists essentially of a rotary converter which was hooked directly to a D. C. lighting source. The converter thus supplied alternating current which was stepped-up by a transformer from 60 volts to about 2300 volts. This high voltage was passed through resistance which cut down the amperage to a very low and limited range. The actual amperage within a small range could be regulated by a rheostat. The current used was .2 milliamperes. It was believed that using a voltage this high would practically eliminate the factor of variation in skin resistance between subjects.

The circuit from the shock-box (indicated in figure 1) was connected with the other pair of the commutators driven by the synchronous motor. From one of this pair of commutators a lead went to the wrist band which was fastened to the reactor's wrist. This wrist band was a thin piece of phosphor-bronze held in place by an elastic band. From the other commutator a lead went to the button of the reaction key. The shock was not used during

all performances of the subject; so when it was not desired, the circuit could be cut out entirely by a hand switch. The wrist band was strapped to the subject's wrist. Contact was made with the button of the key when reacting to the light stimulus. In this way the shock circuit was completed through the body, key, and wrist band.

was connected with the pair of commutators which regulated the light stimulus. The other pen was connected with the reaction key circuit in such a way that a mark of the pen was made whenever the key was pressed, regardless of the stimulus. The two pens were set together so that the relation between the occurrence of the

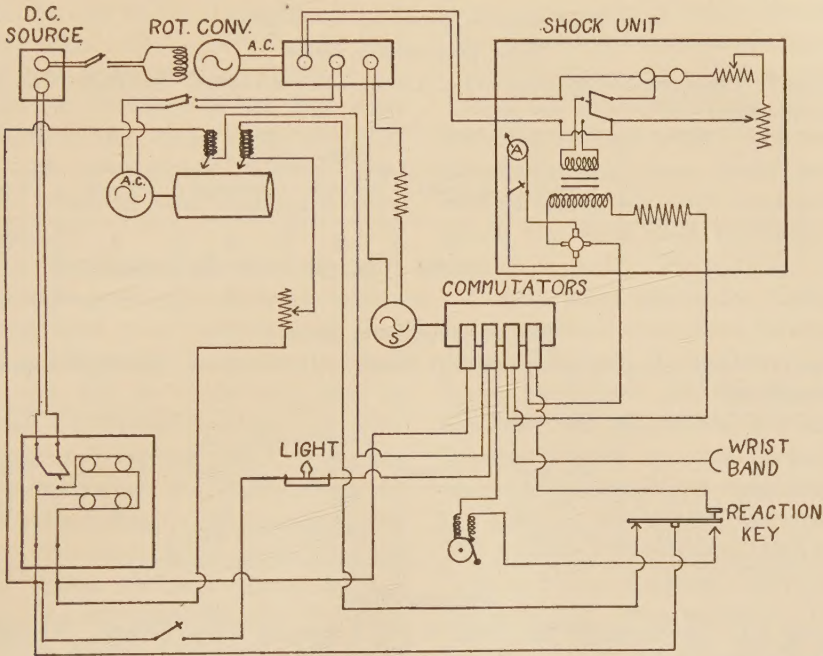


FIG. 1

When both commutators were closed, the shock circuit was shorted through the commutators, and the subject could receive no shock, whether he touched the reaction key or not. If the shock circuit were not closed through the commutators, the current would pass on down to the wrist band and to the button of the reaction key.

The last unit was a continuous paper kymograph device with two electromagnetic activated pens. One pen

stimulus and the reaction could be obtained from the record.

For the coördination of these four units, the two pairs of commutators were arranged so that the stimulus circuit would be made and the shock circuit would be shorted simultaneously.

SUBJECTS

Both children and adults were used in the experiment. These may be considered as constituting the two

major groups of subjects. In the main experiment the adult group consisted of 20 persons, 9 men and 11 women. All but 4 of these were graduate students in the Psychology department of the Johns Hopkins University. Another group of 10 adults

the experiment were members of the Johns Hopkins Child Institute. Three separate series were given with children as subjects. There were 19 children, 13 boys and 6 girls, who took part in the first series; 12 boys in the second series; 22 children, 13 boys and

TABLE 1
Chronological grouping of children

First preliminary series

Group I. Chronological age range—1 yr. 11 mos. to 5 yrs. 11 mos. Intelligence quotient range—96-161.

	CHRONOLOGICAL AGE					Total
	Under 2 years	2-3 years	3-4 years	4-5 years	5-6 years	
No.	1	4	6	4	4	19
I. Q.	111	110-161	100-137	96-138	100-137	

Second preliminary series

Group II. Chronological age range—1 yr. 8 mos. to 4 yrs. 10 mos. Intelligence quotient range—107-161.

	CHRONOLOGICAL AGE					Total
	1-2 years	2-3 years	3-4 years	4-5 years	5-6 years	
No.	2	1	6	3	0	12
I. Q.	107-130	161	120-150	112-121		

Learning series

Group III. Chronological age range—2 yrs. 9 mos. to 5 yrs. 10 mos. Intelligence quotient range—89-161.

	CHRONOLOGICAL AGE					Total
	1-2 years	2-3 years	3-4 years	4-5 years	5-6 years	
No.	0	1	14	6	1	22
I. Q.		161	89-150	111-133	121	

participated in a preliminary series previous to the final "learning" series. This group included 4 men and 6 women. Nine of these individuals took part in both sections of the experiment.

All of the children who took part in

9 girls in the third series. In the following table (table 1) are shown the age range and the number of children in each age group for the three series. The I. Q. range taken on the Stanford Revision of the Binet scale is also given in this table.

PROCEDURE

For adults

For the preliminary tests the rate of the flash was one every second. Forty-five stimuli were given, fifteen of which were without shock and thirty were with shock. The subjects were not instructed concerning the shock until the beginning of the last fifteen of the thirty shock stimuli. At that time they were informed that a shock would be received if the key were pressed at any time when the light was off. The same subjects were given a second trial under the same conditions.

For the "learning" series the subjects were given the following written instructions at the beginning of each trial. "When you look into the black box, you will see a red light flash on and off. If the key is pressed when the light is on, a bell will ring. If the key is pressed when the light is off, the bell will not ring. Your problem is to touch the key quickly every time the light comes on, and make the bell ring. At the signal 'Ready—Go' start tapping the key with each flash of the light. Continue until the signal 'Stop' is given. Be sure to tap the key only while the light is on." Forty-five stimuli were given at a rate of one every two seconds for each trial, 15 of which were without shock and 30 of which were with shock. Ten trials were given. Knowledge of the shock was not given until the beginning of the last 15 of the 30 shock stimuli of the first trial. It was not necessary to repeat this after the first trial. Three individuals were unable to synchronize perfectly at the end of the 10 trials so

additional trials were given until one perfect synchronization trial was obtained.

For children

The first preliminary test consisted of two trials. The rate of the flash was one every second and a half. Ten reactions were taken without the shock and twenty with the shock regardless of the number of stimuli required for the number of reactions.

The second preliminary test also consisted of two trials. The rate of the flash was once every second. Forty-five stimuli were presented to which the child was to react. No shock was used for these trials.

For the main test or the "learning" series ten trials were given on separate days. The rate of the flash was one every two seconds, and the duration of the flash was two-thirds of a second. It was found by the preliminary tests that a rate faster than this was too difficult for children of this age. The following instructions were given. "Let us lift up this door. Do you see the red light? Now watch it. It goes off and on, doesn't it? If we touch this button real quickly when the light is on, a bell will ring; like this"—demonstration—"Now you try it. Touch the button whenever the light is on and make the bell ring." Practice was given on touching carefully and quickly. "That's fine. Now let's put the door down; when I lift it up, you be ready to touch the button. When I say 'Go' see if you can touch the button each time the light is on and make the bell ring. Get your finger ready—"Ready—Go"—touch the button every time the light is on." Practice was

given before a record was taken for the first two trials. Forty-five stimuli were given for each trial, 15 of which were without shock and 30 with the shock. The subjects were not told of the shock until 15 stimuli had been given or unless they stopped reacting, in which case they were informed that they would get a "buzz" if they touched the key when the light was off. It was found after two or three trials that twelve children were too "afraid" of the shock to obtain satisfactory results by using it; so, the shock was not used in the remainder of the trials for those children. All other conditions remained the same.

Motivation

The experiment itself proved to be very interesting to the children, but for further motivation each child was given a cord with one colored bead on it at the end of the first trial. After each practice period the child was given one or two beads to string on his cord. All of the cords were kept in the experimental room until the end of the series, then the child was given his string of beads.

RESULTS

Before considering the results obtained in the experiment, it would be well to discuss briefly the nature and characteristics of the graphic records which were obtained of the subjects' performances and from which the quantitative measurements were secured.

By the use of electro-magnetic markers, two separate lines were drawn upon the continuous roll of record paper—a time line and a reaction line.

The time line showed a deflection each time the red light flashed on and off, and at the same time gave an indication of the length of time the light was on. The reaction line varied quite independently of the time line and showed a mark each time the reaction key was depressed.

It is quite evident that the reaction marks and the time marks for any single record may stand in any relation to one another. That is, the reaction mark may show that the reaction took place during the time the light was on, or it may show that the reaction occurred at varying intervals before or after the light flashed.

In order to make use of all reactions, whether correct or incorrect, and in order to facilitate handling of the measurements, all reactions which were made were consigned to some one of four separate categories or types of reactions. These four classes of reactions were chosen and named because a predominance of responses seemed to fall into four well-defined groups and the name given to each group is typical of the spatial position of the reaction in that group with respect to the time line.

The first group was termed "synchronizing reactions" or "synchronizations." Only those reactions which were made and completed during the time the light was on were included in this group. Such a reaction can be called a movement which the subject has accurately synchronized with the recurring stimulus or red light.

A second class of possible reactions made by the subjects was the type termed "asynchronizations" or complete misses. In this group fell those

responses which were initiated and terminated during the time the red light was off. This type was a complete miss or error inasmuch as the complete movement took place between flashes and the instructions were to depress the reaction key while the red light was on.

A third type of response was that called "anticipatory reaction" or "anticipation." This type was characterized by the fact that the reaction was commenced and the key was depressed prior to the appearance of the red light,

cating that the subject delayed the final portion of his reaction.

These four types of reactions are illustrated in figure 2.

It must be mentioned that these types of movement are only characteristic of the great majority of responses. However, in some cases responses occurred which were difficult to consign to any one category. For example, a child may have kept the key depressed for a time during which any number of stimuli were presented. Such reactions did occur at times and were

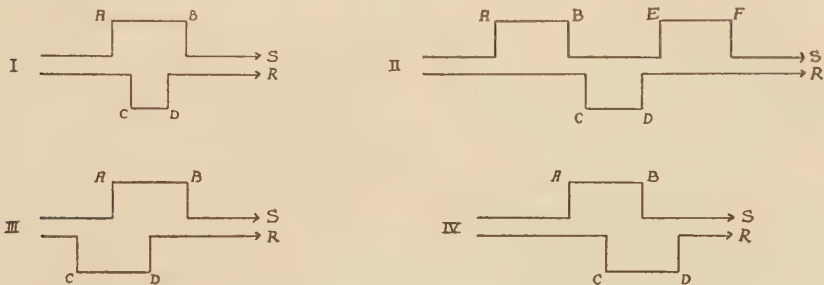


FIG. 2. TYPES OF RESPONSE

S indicates stimulus line, R indicates reaction line. AB represents the duration of the flash of light. CD represents the duration of the complete reaction. I indicates synchronized reaction; II, asynchronized reaction; III, anticipated reaction; and IV, lagged reaction.

yet the reaction was completed during the flash. In other words, the beginning of the reaction anticipated the light, but a portion of the response was synchronized with the light.

A fourth and final class of responses was that in which the reaction of the subject was initiated during the period the light was on and the first part of the movement was accordingly synchronized with the stimulus, but the subject failed to complete the reaction by the time the light was extinguished. This type of reaction was designated as a "lagging reaction" or "lag" indi-

handled as best they could be. Another factor to be considered in the types of reactions made was the fact that quite often, especially among the younger children, the subject failed to react at all. These failures to react appeared in numbers sufficient to warrant their consideration and account will be taken of them in the results obtained.

In the discussion of the curves and tables which embody the results, the criterion of learning is taken as an increase in the number of correct responses made during the final trials

in the series as against the number of correct responses made on the first few trials. Correct responses are those which have been classified as perfect "synchronizations" in the above discussion of types of reactions. In the curves which follow, if the line indicating the number of synchronizations shows a marked rise in level, this is taken as an indication of learning. Although this criterion of learning depends essentially upon the trend of the synchronization curve, nevertheless it is apparent that any quantitative change in the other types of reactions may throw considerable light upon the process of acquiring the correct response. The elimination of the incorrect movements is equally important in the learning process, and if it can be demonstrated that throughout the series of trials, the number of incorrect responses diminishes as the number of correct responses increases, then there is no hesitation in asserting that learning has taken place.

In the learning series the total group of children was handled throughout the experiment as a single group. Very soon after the beginning of the investigation it was noticed that the results given by the older children were characteristically different from those given by the younger children. As indicated earlier in this article, the age range of the children was from two to six years, and it is not startling that within a range this great, differing types of results were obtained. The differences between the two groups could be observed in their interest in the situation, in the difficulty with which their attention was held, and in their abilities in motor coördination.

As a result of this differentiation, the number of children was considered as two separate sub-groups. But another complication appeared very soon after the introduction of the electric shock into the experimental situation. Some children of both the younger and the older groups tended to become "emotionally upset" as soon as this element was involved. Furthermore, instead of growing accustomed to the shock, some of these children grew more and more "afraid" and more difficult to handle. This antagonism to the shock continued in spite of the fact that the shock was relatively light and so arranged that it could not possibly injure the children. Accordingly, after the third or fourth trial, the shock was discontinued for those children who appeared to be too much disturbed by it. As stated previously, some of these children were members of the older group and some belonged in the younger group. The group of children was therefore divided into four sub-groups, as follows: (1) older children on whom the shock was used throughout; (2) older children with the shock removed after the initial trials; (3) younger children on whom the shock was used throughout; and (4) younger children with the shock removed after the initial trials. The older group with shock used throughout consisted of 6 boys and the older group tested without the shock consisted of 5 children, 4 girls and 1 boy. Of the younger group only 4 boys made up the group receiving the shock throughout and 7 children, 5 girls and 2 boys fell into the group which was tested throughout without the shock. A discussion of

the results of each group taken separately follows.

RESULTS OF THE GROUPS RECEIVING SHOCK THROUGHOUT THE TEN TRIALS

Younger group

In table 2 the average number of each type of response is given for each 15 stimuli presented in the first, fifth, and tenth trials. It may be noted from this table that there is an increase in the average number of synchroniza-

in the level of the columns representing the number of synchronizations is apparent. It may also be noted that from the second trial on, the lag type of error is the predominant type of error made. For the first five trials all types of reactions were made with no one type definitely predominating, yet with a slight decrease in the number of asynchronization and omission errors which are considered the most erroneous responses in that in neither one is any part of the reaction syn-

TABLE 2

TYPES OF RESPONSE	TRIAL I				TRIAL V				TRIAL X			
	1	2	3	T.	1	2	3	T.	1	2	3	T.
A	3.5	0.7	0.0	4.2	3.5	3.5	3.2	10.5	7.0	7.0	6.2	20.2
B	5.0	5.5	2.5	13.0	2.7	2.5	3.5	8.7	1.7	3.0	1.7	7.4
C	4.2	2.0	3.4	9.4	5.7	2.5	2.7	11.0	4.2	1.7	3.7	9.7
D	3.5	1.5	1.5	6.5	3.5	2.0	3.0	8.5	1.7	1.5	2.5	5.7
E	0.5	5.2	6.3	12.0	0.2	4.0	3.5	8.3	1.2	2.2	1.2	4.7

Average number of each type of response for trials I, V, and X for the younger group with shock used throughout. The vertical columns numbered 1 represent the response to the first 15 stimuli presented without shock; columns numbered 2, to the second 15 stimuli accompanied by shock; columns numbered 3, to the third 15 stimuli accompanied by shock; and columns lettered T, to the total of 45 stimuli. Row A represents the average number of synchronizations; row B, anticipations; row C, lags; row D, asynchronizations; row E, omissions.

tions made, and a decrease in the average number of errors, the greatest reduction being in the number omitted and the next in the number anticipated. The anticipations and omissions occurred most frequently in the first trial and the lag error most frequently in the tenth trial. There were approximately four times as many correct responses made on the tenth trial as were made on the first.

In figure 3 is illustrated the proportion of the types of responses made on each trial for the ten trials. The rise

chronized with the stimulus. From the sixth trial on, the synchronization type of response definitely predominates.

Learning is indicated from these facts. The process appeared to be first that all types of responses were made; second, the most erroneous responses decreased in number first; third, the partially synchronized reactions next decreased in number; fourth, a slow and then a rapid increase in the number of synchronizations was made.

Older group

The average number of each type of response for trials one, five, and ten is

rect responses on the tenth trial as he did on the first. The number of asynchronizations and omissions decreased decidedly. For this group

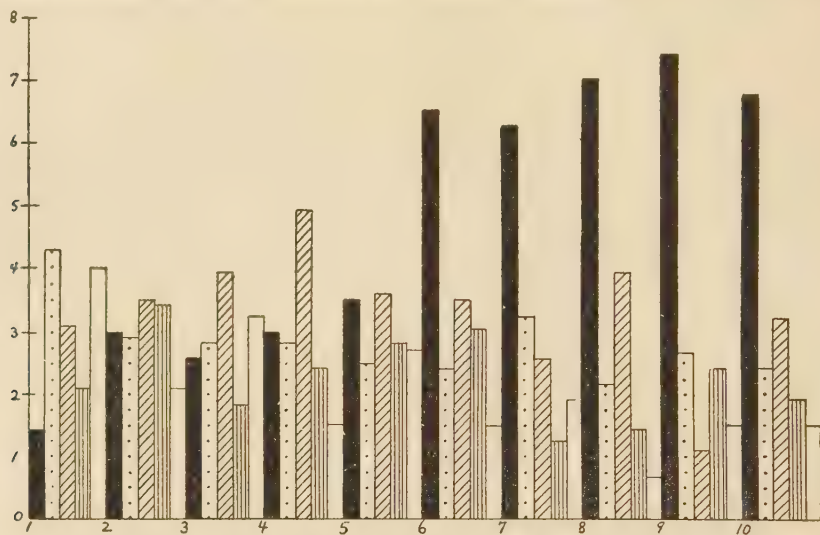


FIG. 3. YOUNGER GROUP, SHOCK USED THROUGHOUT

A group histogram in which are illustrated the types of responses on each trial for 10 trials. The successive trials are given on the abscissa; the average number of responses to 15 stimuli for the group is indicated on the ordinate. The solid column represents the synchronizations made; the dotted column, the number of anticipations; the oblique-line column, the number of lags; the vertical line column, the number of asynchronizations; and the blank column, the number of omissions.

TABLE 3

TYPES OF RESPONSE	TRIAL I				TRIAL V				TRIAL X			
	1	2	3	T.	1	2	3	T.	1	2	3	T.
A	4.5	4.6	4.3	13.5	7.5	5.1	6.5	19.1	9.3	9.0	7.8	26.1
B	1.2	2.1	1.3	4.5	1.5	1.6	0.8	3.9	2.3	2.5	2.1	6.9
C	3.3	2.5	1.6	7.5	3.5	4.0	4.8	12.3	1.6	1.6	2.6	6.0
D	2.6	4.0	3.6	10.3	1.0	1.0	1.8	3.8	0.0	0.1	0.6	0.8
E	3.8	2.1	3.8	9.8	1.5	3.1	2.5	7.1	1.5	1.5	1.8	4.8

Average number of each type of response for trials I, V, and X for the older group with shock used throughout. The vertical columns numbered 1 represent the response to the first 15 stimuli presented without shock; columns numbered 2, to the second 15 stimuli accompanied by shock; columns numbered 3, to the third 15 stimuli accompanied by shock; and columns lettered T, to the total of 45 stimuli. Row A represents the average number of synchronizations; row B, anticipations; row C, lags; row D, asynchronizations; row E, omissions.

given in table 3. Again the number of synchronizations increases. Each child made about twice as many cor-

the number of anticipation and lag errors was approximately the same at the end of the series.

Figure 4 illustrates the proportions of the types of responses made in each trial. The steady rises in the level of the black columns representing the number of synchronizations may be noted; also, the corresponding decrease in the number of errors. For the first three trials no one type of response appears predominately. In the fourth

ess seem to occur for this group as for the younger.

Adults

In table 4 are given the average number of each type of response to each 15 stimuli for the first, fifth, and tenth trials. Although the number of synchronizations on the first trial is large,

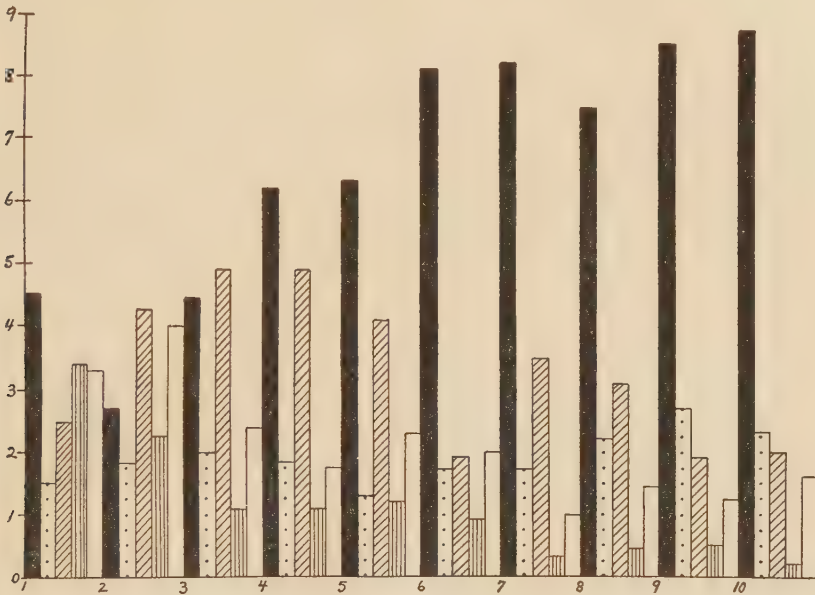


FIG. 4. OLDER GROUP, SHOCK USED THROUGHOUT

A group histogram in which are illustrated the types of responses on each trial for 10 trials. The successive trials are given on the abscissa; the average number of responses to 15 stimuli for the group is indicated on the ordinate. The solid column represents the synchronizations made; the dotted column, the number of anticipations; the oblique-line column, the number of lags; the vertical line column, the number of asynchronizations; and the blank column, the number of omissions.

and fifth trials differentiation occurs in which the synchronized and lag responses predominate. From the sixth trial on further differentiation occurs in which the synchronized is definitely the predominant type. The omissions and asynchronizations are practically eliminated by the end of the series.

The same steps in the learning proc-

yet there is an increase, and there is a decrease in all the types of errors. No omissions were made by this group. The lag type of error was the principal type of error, and it shows a marked reduction. The most erroneous reactions were made infrequently by this group; while there were quite a number of partially synchronized reactions.

The results of these three groups may be contrasted and summarized as:

1. Learning occurred in all three groups as was indicated by the increase in the number of synchronizations, and the decrease in the number of all types of errors.

2. The process of the learning appeared in the two children's groups to be: (1) all types of responses with no one type predominating for the first

than did the younger group; and further, they showed the differentiation of responses at an earlier stage. The adults made many more correct responses on the first trial than did the older group of children and their increase in correct responses began earlier than the children's. These facts, although based upon results of small groups show clearcut age differences in the ability to cope with the conditions of this problem.

TABLE 4

TYPES OF RESPONSE	TRIAL I				TRIAL V				TRIAL X			
	1	2	3	T.	1	2	3	T.	1	2	3	T.
A	13.6	13.5	13.5	40.6	13.8	14.5	14.3	42.6	15.1	14.5	14.5	44.1
B	0.1	0.1	.05	.25	.05	.05	0.1	0.2	.05	0.0	0.0	.05
C	1.2	1.3	1.4	3.9	1.1	0.4	0.2	1.7	0.2	0.4	0.5	1.1
D	.05	.05	0.0	0.1	0.0	0.0	0.0	0.0	.05	0.0	0.0	.05
E	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Average number of each type of response for trials I, V, and X for adults. The vertical columns numbered 1 represent the response to the first 15 stimuli presented without shock; columns numbered 2, to the second 15 stimuli accompanied by shock; columns numbered 3, to the third 15 stimuli accompanied by shock; and columns lettered T, to the total of 45 stimuli. Row A represents the average number of synchronizations; row B, anticipations; row C, lags; row D, asynchronizations; row E, omissions.

few trials; (2) differentiation was first shown by the decrease in the number of asynchronizations and omissions made and slight increase in the number of synchronizations made; (3) further differentiation was shown by fewer asynchronizations and omissions, a decrease in anticipations and lags, and a definite increase in the number of synchronizations made. The modification in responses by adults consisted in the decrease first in the asynchronization error and then in the lag and anticipation errors.

3. The older group of children made more correct responses on the first trial

RESULTS OF GROUPS FOR WHOM THE SHOCK WAS REMOVED AT THE END OF THE FIRST FEW TRIALS

Younger group

In table 5 is given the average number of each type of response for the first, fifth, and tenth trials. It may be noted that for this group all types of responses increase in number, the number of synchronizations showing the greatest increase. Each child on the average made seven times as many correct responses on the tenth trial as he made on the first. The predominant type of response throughout

the series was that of anticipation; failure to react. Only after the shock the least frequent response was the asynchronization type. A notable start reacting positively to the problem.

TABLE 5

TYPES OF RESPONSE	TRIAL I				TRIAL V				TRIAL X			
	1	2	3	T.	1	2	3	T.	1	2	3	T.
A	1.0	0.5	0.1	1.6	3.0	1.1	2.3	6.4	3.1	2.5	2.1	7.7
B	4.3	2.1	1.8	8.2	5.0	5.1	4.4	14.5	4.9	5.0	6.0	15.9
C	2.1	1.4	1.4	5.0	4.0	4.0	2.2	10.2	2.6	3.5	2.3	8.5
D	2.1	0.5	0.5	3.4	1.1	1.0	1.5	3.7	1.6	1.8	1.5	5.0
E	5.5	10.1	11.1	26.8	1.8	3.4	3.8	9.1	2.8	1.6	2.8	7.3

Average number of each type of response for trials I, V, and X for the younger group with shock removed. The vertical columns numbered 1 represent the response to the first 15 stimuli; columns numbered 2, to the second 15 stimuli; columns numbered 3, to the third 15 stimuli presented; and columns lettered T, to the total of 45 stimuli. (Shock was removed after the second or third trial.) Row A represents the average number of synchronizations; row B, anticipations; row C, lags; row D, asynchronizations; row E, omissions.

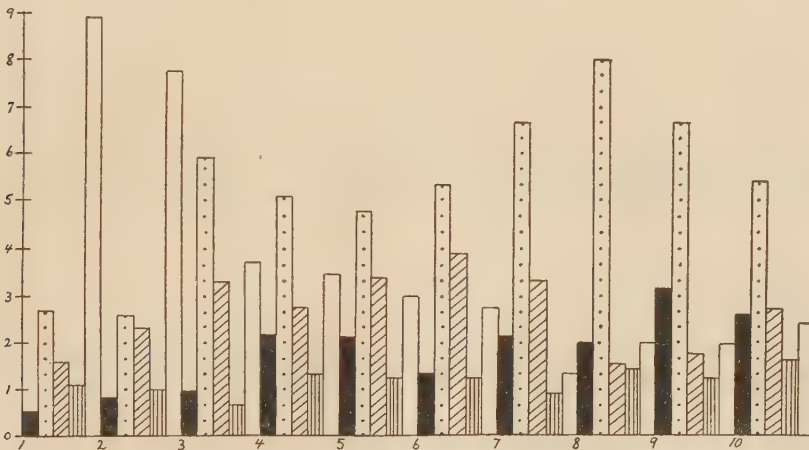


FIG. 5. YOUNGER GROUP, SHOCK REMOVED

A group histogram in which are illustrated the types of responses on each trial for 10 trials. The successive trials are given on the abscissa; the average number of responses to 15 stimuli for the group is indicated on the ordinate. The solid column represents the synchronizations made; the dotted column, the number of anticipations; the oblique line column, the number of lags; the vertical line column, the number of asynchronizations; and the blank column, the number of omissions.

fact brought out in this table is the large reduction in the number of omissions. The typical mode of behavior to the shock in this group was

These facts are shown more clearly by the graph in figure 5 which gives the types of responses for each of the ten trials. Here it is clearly seen how

as soon as the shock is removed, the level of the columns representing the number of omissions drops quite low and remains so throughout the series. For trials 3 to 7 the anticipation and lag type of reaction predominate, although there is a slight increase in the number synchronized. From the seventh trial on the anticipation type becomes outstanding and the number of synchronizations increases to some extent.

rors and correct responses, the partially correct responses constituting an intermediate stage in the process. The majority of reactors progressed by reducing the asynchronization and omission stage first, then reducing the partially incorrect responses. It may be concluded that learning has occurred in the reduction of absolutely incorrect responses, although the stage of perfect synchronization has not been reached.

TABLE 6

TYPES OF RESPONSE	TRIAL I				TRIAL V				TRIAL X			
	1	2	3	T.	1	2	3	T.	1	2	3	T.
A	1.8	1.0	0.2	3.0	4.4	2.8	1.0	8.2	1.2	2.0	2.0	5.2
B	3.8	2.0	1.4	7.2	4.0	4.4	4.8	15.2	5.5	4.2	5.0	14.7
C	2.8	1.6	1.2	5.6	2.8	1.6	3.0	7.4	4.7	4.2	4.0	12.9
D	3.0	1.0	1.0	5.0	2.0	2.6	1.8	6.4	1.5	1.2	1.0	3.7
E	3.6	9.2	11.0	23.8	2.2	4.2	4.0	10.4	2.0	2.2	3.0	7.2

Average number of each type of response for trials I, V, and X for the older group with shock removed. The vertical columns numbered 1 represent the response to the first 15 stimuli presented; columns numbered 2, to the second 15 stimuli; columns numbered 3, to the third 15 stimuli; and columns lettered T, to the total of 45 stimuli. (Shock was removed after the second or third trial.) Row A represents the average number of synchronizations; row B, anticipations; row C, lags; row D, asynchronizations; row E, omissions.

The high anticipation and lag curve rather than a high synchronization curve at the end of the series might be expected for this group, because of the fact that when making either one of these types of reactions, no warning was given and no factor was present to bring about a correction. But it might be concluded that a certain degree of learning did occur with this group in the sense that the errors of greatest extent decreased the most, and the partially correct responses increased in number. This would hold only under the assumption that a gradation exists between the absolute er-

Older group

In table 6 is presented the average number of each response for trials 1, 5, and 10. It may be noted from this table that the number of correct and partially correct responses increases, while the number of asynchronizations and omissions decreases. The anticipation type of reaction is the predominant type of reaction throughout the series. Figure 6 illustrates these facts even more clearly. The shock was removed on later trials for this group than for the younger group, but the reduction of the number of omissions

is quite noticeable. The large differentiation in response comes clearly on the eighth trial, when the anticipation type increases decidedly and all other types of errors decrease in number to a large extent.

The results of these two groups may be summarized and compared as: (1) a certain degree of learning occurred in that there was a decrease in the most erroneous types of reactions

stimulus pattern. By one (groups receiving the shock throughout) the general attitude was to avoid the shock by paying more careful attention to each reaction, attempting to press the key at just the right time. By the other (groups having the shock removed) the general attitude was to avoid the shock by simply not reacting. This factor for the entire experiment had to be overcome before a good

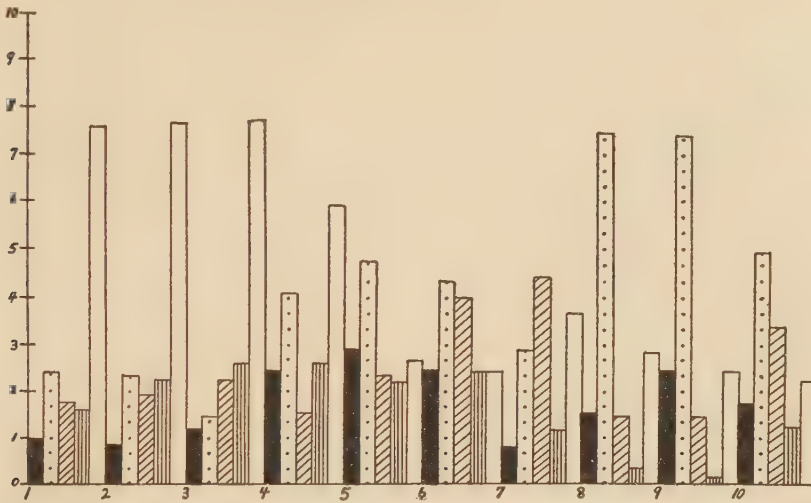


FIG. 6. OLDER GROUP, SHOCK REMOVED

A group histogram in which are illustrated the types of responses on each trial for 10 trials. The successive trials are given on the abscissa; the average number of responses to 15 stimuli for the group is indicated on the ordinate. The solid column represents the synchronizations made; the dotted column, the number of anticipations; the oblique-line column, the number of lags; the vertical line column, the number of asynchronizations; and the blank column, the number of omissions.

and an increase in the correct and partially correct types of response; (2) the predominant type of response was that of anticipation for both groups; (3) the typical form of behavior when the shock was used was that of failure to react.

EFFECT OF THE SHOCK

(1) It might be said that there were two general types of response to the

synchronization record could possibly be obtained.

(2) For the groups who received the shock throughout, a greater amount of learning occurred than with the group that had the shock removed. So that for the entire series it might be concluded that the shock was beneficial for the learning process. Its effectiveness was probably in its corrective value. That is, that by the shock the

subjects were aware of any error they made. However, in any one trial it was found that more synchronization reactions and fewer errors were made to the stimuli not presented with shock than to the stimuli accompanied by the shock. (The writer is cognizant

may be surmised, however, from the results found, that with such a group, the partially correct responses would predominate, because the directions would be followed and no check would be made on a slight anticipation or lag reaction.)

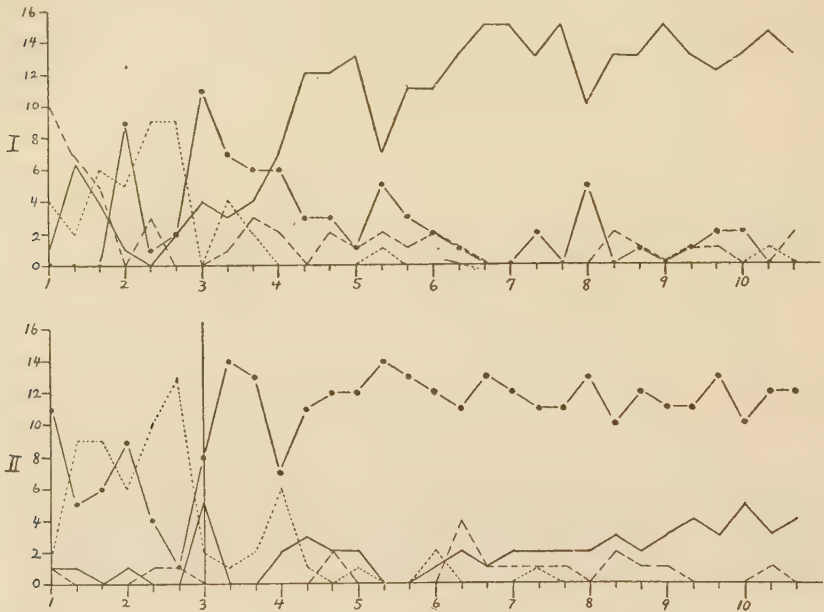


FIG. 7. SETS OF CURVES FOR TWO INDIVIDUALS IN WHICH ARE SHOWN THE TYPES OF REACTION ON EACH TRIAL FOR 10 TRIALS

The abscissa represents the successive trials; the number of responses to each 15 stimuli is indicated on the ordinate. The solid line represents the number of synchronizations made; the dot and dash line, the number of anticipations plus the number of lags; the broken line, the number of asynchronizations; and the dotted line, the number of omissions. Set I is of a child in the older group, shock used throughout; set II, child in the younger group, shock removed.

of the fact that a comparison of the results of these two main groups with regard to the shock is not conclusive except for the effects as such, due to the fact that the shock was administered to all children at some time in the experiment. There was no group which learned the problem without experiencing the electric shock. It

INDIVIDUAL DIFFERENCES

In each group wide individual differences were found. Figure 7 illustrates two sets of curves of individuals' responses made throughout the series. From these it may be suggested that no two individuals progressed in the same way.

SEX DIFFERENCES

(1) In the children's group no girl received the shock throughout. The girls showed much more "emotional disturbance" than did the boys.

(2) Of the group who did not receive the shock the boys had a slightly higher average of correct responses than did the girls.

(3) Of the adults, the men were slightly superior as to the number of correct responses made to the women, and the men showed an increase in the correct responses at an earlier stage than did the women.

(These sex differences are given as suggestive differences only, as conclusive statements could not be made upon the results of such small groups.)

SUMMARY AND CONCLUSIONS

The problem of learning to make rhythmic responses was studied with such instrumental control that evidence was obtained on the various stages in the learning process. The types of responses at each stage of learning showed modifications through which more accurate synchronization was established. The types of responses made fell largely into five well-defined categories;—synchronizations or correct responses, in which the complete reaction was made during the flash of light; asynchronizations or complete misses, in which the complete reaction was made when the light was off; anticipations, in which the reaction was commenced prior to the flash but was completed while the light was on; lags, in which the reaction was commenced while the light was on but was

completed when the light was off; and omissions, in which case there was failure to react to a stimulus.

Twelve children were too "disturbed" by the shock to continue with the experiment unless the shock was removed. Because it was thought desirable to ascertain the reactions of these children to the problem, the shock was eliminated for this group after the third or fourth trials.

The types of responses which were elicited throughout the series by the entire group of children who received shock in each trial were: (1) no one type of response predominated in the first three trials (2) the number of synchronizations increased steadily so that in the last few trials, this type of reaction predominated; (3) of the errors made, the lag type occurred most frequently; (4) the asynchronizations and omissions were few in number by the end of the series.

The types of responses which were made in the series by the group who had the shock removed were: (1) failure to respond until the shock was removed; (2) when reactions were made during the shock trials, few were accurately synchronized; (3) for the last few trials, the anticipation type of reaction increased rapidly in number and was the predominant type of response; (4) the number of synchronizations increased slightly toward the end of the series; (5) relatively few asynchronizations and omissions were made in the last trials.

The types of response for adults were: (1) the synchronization type of reaction was predominant throughout the series; (2) the lag type of error was the most prevalent error made;

(3) some form of reaction was made to every stimulus presented.

CONCLUSIONS

1. Learning occurred for all groups. For those who received the shock throughout, the learning was more rapid and continued to a higher level than for those who did not.

2. Wide individual differences and methods of learning occurred in all groups.

3. The effects of the shock were: (a) seeming "emotional disturbance" on the part of all the girls in the children's group, and on the part of some boys; (b) of those who showed such disturbance, the typical mode of behavior was failure to react. Only after the shock was removed, was the problem attacked; (c) a greater extent of learning occurred from those who received the shock throughout than from those who did not; (d) of those who received the shock throughout, in any one trial more synchronizations were made to the stimuli when the shock was not used.

4. Age differences found were: (a) the adults began at a higher level of correct responses than did the children, and increased in the number of correct responses at a faster rate; (b) the older group of children began at a higher level than did the younger group and showed differentiation of response at an earlier stage.

5. The sex differences found were: (1) for the children, no girl received the shock for the entire series; (2) more "emotional disturbance" was manifested when the shock was used by the girls than by the boys; (3) of the group who had the shock removed, the boys synchronized on the average more times than did the girls; (4) for the adults, the men were slightly superior to the women. Fewer errors were made, and the errors were eliminated on the average at an earlier stage by the men than by the women.

(Note: The complete data for this experiment may be obtained from the doctoral dissertation on file at the Johns Hopkins University.)

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